A GENERAL PROCEDURE TO SET UP THE DYADIC GREEN'S FUNCTION OF MULTILAYER CONFORMAL STRUCTURES AND ITS APPLICATION TO MICROSTRIP ANTENNAS

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***Abstract*-This paper presents a generalized approach to derive the dyadic Green's function of arbitrary multilayer structures in planar, cylindrical and spherical coordinate systems. It is based on a full-wave equivalent-circuit representation that makes it possible to apply simple network analysis techniques. The planar stratified structures may be laterally bounded or open, the cylinders or spheres circumferentially closed or limited sectors. The procedure can be extended to other coordinate systems and anisotropic materials by means of a generalized transmission-line approach. For a demonstration of the applicability of this method, the derivation of the dyadic Green's functions in spectral domain of some commonly used cylindrical and spherical microstrip structures is presented.**

I. INTRODUCTION

Apart from several other applications, the dyadic Green's function is often found as kernel in integral-equation technique in combination with the method of moments (MoM) to solve the boundary value problem of microstrip antennas. These may consist of several layers dielectric with metallizations in the interfaces and can have planar, cylindrical, spherical or any other shape. A microstrip structure in a general coordinate system is depicted in Fig. 1.

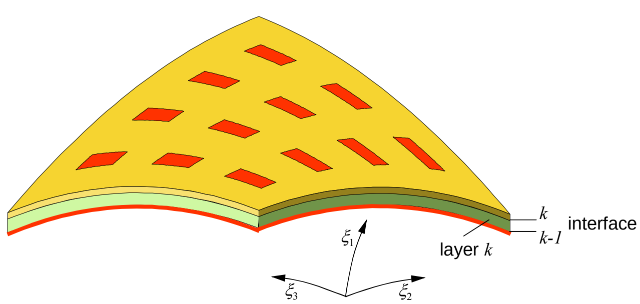

Fig. 1: Conformal multilayer microstrip structure in curvilinear coordinate system.

The derivation of the dyadic Green's function can be done by the use of a full-wave equivalent circuit and was already derived for certain coordinate systems [1], [2], [3]. The general description in curvilinear coordinates has been presented in [4]. The present paper briefly describes the general concept behind and shows two applications of microstrip antennas in cylindrical and spherical coordinates.

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II. ANALYSIS

Starting from the wave equations in different coordinate systems the relation between the tangential field components in spectral domain on both sides of a layer can be derived [1]-[4]

$$\begin{bmatrix} \tilde{\mathbf{E}}_{k-1} \\ \tilde{\mathbf{H}}_{k-1} \end{bmatrix} = \underbrace{\begin{bmatrix} \tilde{\boldsymbol{V}}_k & \tilde{\boldsymbol{Z}}_k \\ \tilde{\boldsymbol{Y}}_k & \tilde{\boldsymbol{B}}_k \end{bmatrix}}_{\tilde{\boldsymbol{K}}_k} \cdot \begin{bmatrix} \tilde{\mathbf{E}}_k \\ \tilde{\mathbf{H}}_k \end{bmatrix}. \qquad (1)$$

The derivation can be done either by following a general curvilinear description [4] or in addition to this, the derivation of above equation was done via the vector potentials for the spherical case in [3]. Here the tangential field components have been derived from the vector potentials and can be described by the coefficients A, B, C, D and the according Hankel functions using four equations. The coefficients are eliminated by setting up the equations on top and bottom of a layer k from which eq. (1) is obtained.
Furthermore the boundary conditions at the interfaces are taken into account by

$$\tilde{\mathbf{H}}_k^+ - \tilde{\mathbf{H}}_k^- = \tilde{\mathbf{J}}_k . \qquad (2)$$

On bottom and top of the whole structure a relation between electric and magnetic field components is set up

$$\tilde{\mathbf{H}}_{0,n} = \mp \tilde{\boldsymbol{Y}}_{0,n} \tilde{\mathbf{E}}_{0,n} , \qquad (3)$$

where the admittance $\tilde{\boldsymbol{Y}}_{0,n}$ is determined by either having open or closed boundaries below or above the multilayered structure.
Eqs. (1)-(3) are the starting point for the general description of multilayered structures by the use of a full-wave equivalent circuit. Fig. 2 shows the equivalent circuit, containing the above equations.

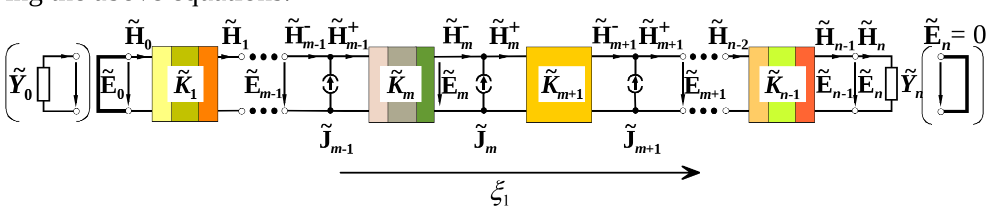

Fig. 2: Full-wave equivalent representation of a conformal multilayer structure, where ξ_1 is the first of the curvilinear coordinates.

Finally the dyadic Green's function in spectral domain is obtained [1]

$$\tilde{\mathbf{E}} = \tilde{\mathbf{G}} \cdot \tilde{\mathbf{J}} . \qquad (4)$$

Now the solution via integral equation technique in combination with spectral domain approach can be used to solve the boundary value problem of microstrip antennas. Exemplarily this is presented for microstrip antennas in two coordinate systems, the cylindrical and the spherical one.

III. APPLICATION

Fig. 3 shows the first application. A single-layer microstrip antenna structure is depicted in cylindrical coordinates. Furthermore the related equivalent circuit is shown.
The dyadic Green's function for the single-layer microstrip structures is obtained as [5]

$$\tilde{\mathbf{G}} = (\tilde{\boldsymbol{Z}}_1^{-1}\tilde{\boldsymbol{V}}_1 + \tilde{\boldsymbol{Y}}_2)^{-1} \ . \tag{5}$$

The matrix components can be obtained as described in [5] or the general formalism in [4] can be used. The procedure is the same, only in [5] the cylindrical coordinates are used right from the beginning, whereas in [4] the derivation is done for general curvilinear coordinates and later on these are replaced by cylindrical ones.

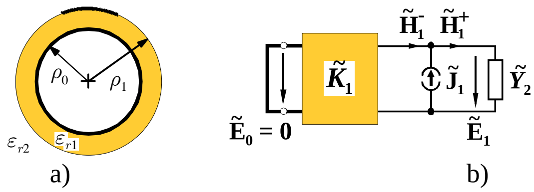

Fig. 3: a) Single-layer microstrip antenna structure in cylindrical coordinates and b) related equivalent circuit.

From the solution of the integral equation the unknown currents are obtained and parameters like input impedance (Fig. 4) or far field patterns can be derived [5].

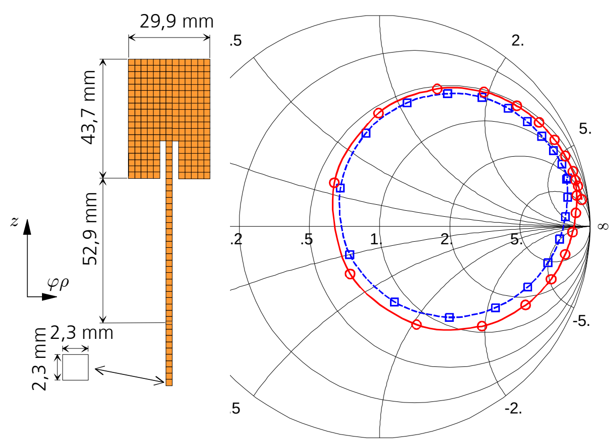

Fig. 4: Input impedance of a direct fed z-oriented microstrip antenna [5]. f_0=2.2-2.4 GHz (clockwise), ρ_0=30 mm, d_1=ρ_1-ρ_0=0.787 mm, ε_{r1}=2.33. Simulation (○), measurement (□).

The general procedure is now applied to the case of a microstrip patch antenna on a circumferentially closed spherical structure of one dielectric layer covering a metallic sphere as shown in Fig. 5. The corresponding equivalent circuit is the same as shown in Fig. 3b).

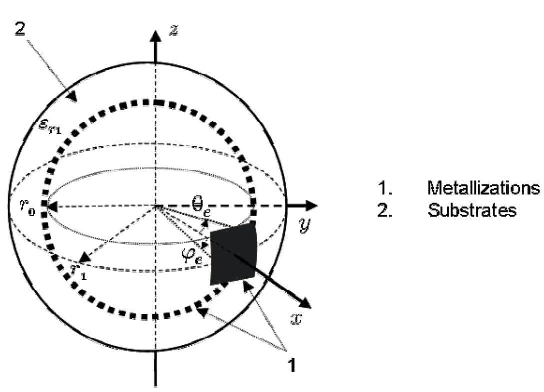

Fig. 5: Microstrip antennas on a circumferentially closed spherical structure.

The Green's function for this structure is expressed as already given in Eq. (5). The matrix elements are now defined by the spherical coordinates, where the sub-matrices $\tilde{\boldsymbol{Y}}_2$, $\tilde{\boldsymbol{Z}}_1$ and $\tilde{\boldsymbol{V}}_1$ of the hybrid matrix can be found in [3].

The calculated input impedance of the φ-polarized patch is compared with commercial software as shown in Fig. 6.

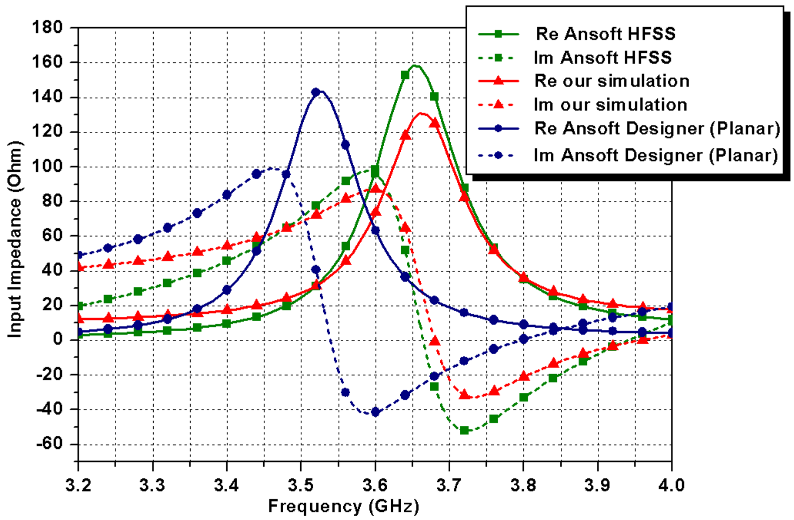

Fig.6: Input impedance of phi-polarized patch r_1=60 mm, r_0=58.42 mm, ε_{r1}=2.52 quasi-rectangular φ-polarized patch with sizes of w_φ=25 mm, w_θ=40 mm.

IV. CONCLUSIONS

A general procedure for the derivation of the dyadic Green's function of arbitrary multilayer structures has been presented. Two applications of single-layer microstrip antennas in cylindrical and spherical coordinates have shown the applicability of the presented approach.

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